

# Abstract

*New advances in computational modeling and instrumentation in the past decade has enabled the use of electromagnetic radiation for non-invasive monitoring of the physiological state of biological tissues. The near infrared (NIR) light having the wavelength range of 600 nm - 1000 nm has been the main contender in these emerging molecular imaging modalities. Assessment of accurate pathological condition of the tissue under investigation relies on the contrast in the molecular images, where the endogenous contrast may not be sufficient in these scenarios. The fluorescence (exogenous) contrast agents have been deployed to overcome these difficulties, where the preferential uptake by the tumor vasculature leads to high contrast, making this modality one of the biggest contenders in small-animal and soft-tissue molecular imaging modalities.*

*In Fluorescence diffuse optical spectroscopy/imaging, this exogenous drug is excited by NIR laser light causing the emission of the fluorescence light. The emitted fluorescence light is typically dependent on the life time and concentration of the exogenous drug coupled with physiology associated with the tissue under investigation. As there is an excitation and emission of the light, the underlying physics of the problem is described by a coupled diffusion equations. These coupled diffusion equations are typically solved by advanced numerical methods, which tend to be computationally demanding.*

*In this work, analytical solutions for these coupled partial differential equations (PDEs) for the regular geometries for both time-domain and frequency-domain cases*

were developed. Till now, the existing literature has not dealt with all regular geometries and derived analytical solutions were only for couple of geometries. Here a universally acceptable generic solution was developed based on Green's function approach that is applicable to any regular geometry. Using this, the analytical solutions for the regular geometries that is encountered in diffuse fluorescence spectroscopy/imaging were obtained. These solutions can play an important role in determining the bulk fluorescence properties of the tissue, which could act as good initial guesses for the advanced image reconstruction techniques and/or can also facilitate the calibration of experimental fluorescence data by removing biases and source-detector variations.

In the second part of this work, the developed analytical models for regular geometries were validated through comparison with the established numerical models that are traditionally used in the diffuse fluorescence spectroscopy/imaging. This comparison not only validated the developed analytical models, but also showed that analytical models are capable of providing bulk fluorescence properties with atleast one order of magnitude less computational cost compared to the highly optimized traditional numerical models.